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Effect of time of spray and plant growth regulators on growth and flowering of muskmelon (*Cucumis melo* L.)

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Abstract
An investigation was carried out on "Effect of time of spray and plant growth regulators on muskmelon (*Cucumis melo* L.)" at College Farm, College of Horticulture, S. D. Agricultural University, Jagudan, Gujarat, India during Summer 2021. The experiment was laid out in Factorial Randomized Block Design with eighteen treatment combinations involving three levels of time of spray *i.e.*, t_1 (2 leaf stage), t_2 (4 leaf stage) and t_3 (2 and 4 leaf stage) and plant growth regulators in six levels *i.e.*, p_1 (NAA @ 100 ppm), p_2 (NAA @ 150 ppm), p_3 (Ethrel @ 100 ppm), p_4 (Ethrel @ 150 ppm), p_5 (GA_3 @ 10 ppm) and p_6(GA_3 @ 20 ppm) in Gujarat Muskmelon 3 variety. T_{18} (Spray at 2 and 4 leaf stage + GA_3@ 20 ppm) found superior on length of main vine (cm) at 60 DAS and at final harvest. Whereas T_{16} (Spray at 2 and 4 leaf stage + Ethrel @ 150 ppm) produced superior results on number of primary branches at final harvest, number of days taken for first male flower, number of days taken for first female flower, number of male flowers per vine, number of female flowers per vine, sex ratio (male: female) and number of days taken from fruit set to edible maturity as compared to the other treatments.

Keywords: 2 and 4 leaf stage, PGR, Sex expression

Introduction
Cucumis melo L. commonly known as Cantaloupe or muskmelon is a member of Cucurbitaceae family. It is known by various names *viz.*, Bachang, Sweet melon, Kalinga, Chira, Kharbuj and Sakkarteti in different parts of India. The ripe fruits are edible while green fruits are used as vegetable. The fruits are extensively used as dessert fruits and are highly popular in hotter months. Melons grown in dry regions are sweeter and tastier than those of a wet situation. Muskmelon is gaining a lot of importance due to its short duration, high production potential with high nutritive value, taste, delicacy and also its suitability for the cultivation under rainfed and irrigated conditions throughout the year. In India, cucurbits occupy the prime place among the various vegetables, which are popular and available in all parts of India. The growing area and production of muskmelon in India were 61 ('000 ha) and 1368 ('000 MT), respectively. (Annon., 2019-20) [2].
Plant growth regulators (PGRs) are organic compounds other than the nutrients that modify plant physiological processes. PGRs, called bio stimulants or bio inhibitors act inside the plant cells to stimulate or inhibit specific enzymes or enzyme systems and thus, regulate the plant metabolism. Normally, they are active in low concentrations in the plants. Growth regulators include both growth promoters and retardants which have shown to modify the canopy structure and other yield attributes (Ansari and Chowdhary, 2018) [3]. Exogenous application of growth regulators has shifted the sex expression by increasing the production of female flower and suppressing that of male flower in cucurbits. Exogenous application of plant regulators altered sex ratio and sequence, when applied at 2 or 4 leaf stage, the critical stage at which the suppression or promotion of either sex is possible. Hence, modification of sex to desired direction was manipulated by exogenous application of plant growth regulators once, twice or even thrice at different intervals (Hossain *et al*., 2006) [10].

Materials and Methods
A field experiment on muskmelon var. GMM3 was conducted at College Farm, College of Horticulture, S. D. Agricultural University, Jagudan, Gujarat, India during Summer 2021. The experiment was laid out in Factorial Randomized Block Design with total eighteen treatments comprising of two factors *viz*., time of spray (t) *viz*., t_1 (2 leaf stage), t_2 (4 leaf stage) and t_3 (2 and 4 leaf stage) and plant growth regulators (p) *viz*., p_1 (NAA @ 100 ppm), p_2 (NAA @ 150 ppm), p_3 (Ethrel @ 100 ppm), p_4 (Ethrel @ 150 ppm), p_5 (GA_3 @ 10 ppm) and p_6 (GA_3 @ 20 ppm).

The combination of treatments comprised of Spray at 2 leaf stage + NAA @ 100 ppm (T_1), Spray at 2 leaf stage + NAA @ 150 ppm (T_2), Spray at 2 leaf stage + Ethrel @ 100 ppm (T_3), Spray at 2 leaf stage + Ethrel @ 150 ppm (T_4), Spray at 2 leaf stage + GA_3 @ 10 ppm (T_5), Spray at 2 leaf stage + GA_3 @ 20 ppm (T_6), Spray at 4 leaf stage + NAA @ 100 ppm (T_7), Spray at 4 leaf stage + NAA @ 150 ppm (T_8), Spray at 4 leaf stage + Ethrel @ 100 ppm (T_9), Spray at 4 leaf stage + Ethrel @ 150 ppm (T_{10}), Spray at 4 leaf stage + GA_3 @ 10 ppm (T_{11}), Spray at 4 leaf stage + GA_3 @ 20 ppm (T_{12}), Spray at 2 and 4 leaf stage + NAA @ 100 ppm(T_{13}),Spray at 2 and 4 leaf stage + NAA @ 150 ppm(T_{14}),Spray at 2 and 4 leaf stage + Ethrel @ 100 ppm(T_{15}),Spray at 2 and 4 leaf stage + Ethrel @ 150 ppm (T_{16}), Spray at 2 and 4 leaf stage + GA_3 @ 10 ppm (T_{17}), Spray at 2 and 4 leaf stage + GA_3 @ 20 ppm (T_{18}) replicated thrice.

The experimental soil was loamy sand, with good drainage condition. As per recommended dose, whole quantity of well decomposed FYM (20 t ha^{-1}) was applied to the experiment field before sowing and mixed thoroughly with the soil and dose of N:P:K (100:50:60 kg ha^{-1}) out of which half dose of the nitrogen (N) and full dose of phosphorus (P_2O_5) and potassium (K_2O) were applied as basal dose in the form of urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. The remaining half dose of nitrogen was applied as top dressing in the form of urea at thirty days after sowing. The planting was done at the spacing of 1.2 m × 1.0 m with plot size 4.0 m × 2.4 m.

The foliar application of plant growth regulators was given as per the treatments. The length of main vine in centimeter was measured at 60 DAS and at final harvest with the help of measure tap from ground level to the tip of the main vine. The number of primary branches was counted at final harvest. All the flowering parameters were noted from the date of sowing and and on the basis of daily observation from each tagged plants except the number of days taken from fruit set to edible maturity. To count the days taken from fruit set to edible maturity, one fruit from each tagged plant was marked separately. Total number of days required from the date of fruit set to the harvesting was recorded. Statistical analysis of the data pertaining to growth and flowering parameters were analysed as per the methods described by Panse and Sukhatme (1985) [16].

Results and Discussion

Growth parameters

The data on growth attributing characters such as length of main vine at 60 DAS and at final harvesting and number of primary branches at final harvest are depicted in Table 1.

Length of main vine at 60 DAS and at final harvesting (cm)

Various time of spray, plant growth regulators and their interaction produced significant effect on length of main vine at 60 DAS and at final harvesting. Significantly maximum length of main vine (139.50 and 246.11 cm) was recorded at 2 and 4 leaf stage (t_3) at 60 DAS and at final harvest, respectively. Maximum length of main vine (142.36 and 247.44 cm) was significantly increased with the application of GA_3 @ 20 ppm (p_6) at 60 DAS and at final harvest respectively among various plant growth regulators. The interaction effect of time of spray and plant growth regulators significantly increased length of main vine (153.41 and 259.76 cm) at 60 DAS and at final harvest respectively with the treatment combination of t_3p_6 (Spray at 2 and 4 leaf stage + GA_3 @ 20 ppm).

The increased vine length with the application of GA_3 might be the result of rapid elongation of internodes by both cell division and cell elongation (Krishnamoorthy and Sandooja, 1981) [12]. These findings are in agreement with the results of Ansari and Chaudhary (2018) [3] in bottle gourd, Kadi *et al.* (2018) [11] in cucumber and Kumari *et al.* (2019) [13] in bottle gourd.

Number of primary branches at final harvest

A perusal of the data reveals that the number of primary branches at final harvest was significantly influenced by time of spray, plant growth regulators and their interaction. Significantly maximum number of primary branches at final harvest (9.64) was recorded at 2 and 4 leaf stage (t_3). Among plant growth regulators, significantly maximum number of primary branches at final harvest (9.47) was recorded with the application of Ethrel @ 150 ppm (p_4). The interaction effect of time of spray and plant growth regulators significantly increased the number of primary branches at final harvest (10.47) with the treatment combination of t_3p_4 (Spray at 2 and 4 leaf stage + Ethrel @ 150 ppm).

Table 1: Effect of time of spray, plant growth regulators and their interaction on various growth parameters of muskmelon (*Cucumis melo* L.)

Plant growth regulators (p)	Length of main vine at 60 DAS (cm)				Length of main vine at final harvest (cm)				Number of primary branches at final harvest			
	Time of spray (t)											
	t_1	t_2	t_3	Mean	t_1	t_2	t_3	Mean	t_1	t_2	t_3	Mean
p_1 (NAA @ 100 ppm)	130.04	130.11	140.44	133.53	237.59	232.41	253.00	241.00	8.20	8.00	8.33	8.18
p_2 (NAA @ 150 ppm)	131.41	130.88	149.55	137.28	238.07	232.54	257.35	242.65	8.27	8.07	8.53	8.29
p_3 (Ethrel @ 100 ppm)	129.44	129.06	120.49	126.33	234.24	230.96	224.13	229.77	9.53	8.13	10.40	9.36
p_4 (Ethrel @ 150 ppm)	127.81	120.26	120.17	122.75	233.55	228.75	223.66	228.65	9.60	8.33	10.47	9.47
p_5 (GA_3 @ 10 ppm)	138.56	131.41	152.95	140.97	241.48	236.48	258.73	245.57	8.20	8.13	10.00	8.78
p_6 (GA_3 @ 20 ppm)	139.88	133.79	153.41	142.36	244.80	237.76	259.76	247.44	8.27	8.20	10.13	8.87
Mean	132.86	129.25	139.50		238.29	233.15	246.11		8.68	8.14	9.64	
	t	p	t × p		t	p	t × p		t	p	t × p	
S. Em. ±	1.99	2.81	4.88		2.31	3.27	5.66		0.15	0.21	0.36	
C. D. (5%)	5.72	8.09	14.01		6.64	9.39	16.27		0.42	0.59	1.03	
C. V. %	6.31				4.10				7.08			

Note: t_1: 2 leaf stage, t_2: 4 leaf stage, t_3: 2 and 4 leaf stage

The increased number of primary branches with ethrel might be due to the ability of ethrel to retard stem elongation, promote lateral branching and manipulate the flowering date. Since, ethylene acts as anti-gibberellins (Hayashi *et al*., 2001) [8]. These findings are in close accordance with the results of Chaurasiya *et al*. (2016) [4] in muskmelon.

Flowering parameters

The data on flowering attributing characters such as number of days taken to first male flower, number of days taken to first female flower, number of male flowers per vine, number of female flowers per vine, sex ratio (male: female) and number of days taken from fruit set to edible maturity are depicted in Table 2 and 3.

Number of days taken to first male flower

Various time of spray, plant growth regulators and their interaction produced significant effect on the number of days taken to first male flower. Significantly minimum number of days taken to first male flower (34.67) were recorded at 2 and 4 leaf stage (t_3). In case of the plant growth regulators, significantly minimum number of days taken to the first male flower (33.91) were noticed with the application of GA_3 @ 20 ppm (p_6). The interaction effect of time of spray and plant growth regulators significantly reduced the number of days taken to first male flower (32.80) with the treatment combination of t_3p_6 (Spray at 2 and 4 leaf stage + GA_3 @ 20 ppm).

The number of days for the initiation of first male flower were reduced because of the GA_3. This might be due to the action of GA_3 which induces maleness in cucurbits. These findings are in accordance with the results of Hossain *et al.* (2006) [10] in bitter gourd.

Number of days taken to first female flower

Various time of spray, plant growth regulators and their interaction produced significant effect on number of days taken to first female flower. Significantly minimum number of days taken to first female flower (38.79) were recorded at 2 and 4 leaf stage (t_3). In case of plant growth regulators, significantly minimum number of days taken to first female flower (38.93) were recorded with the application of Ethrel @ 150 ppm (p_4). The interaction effect of time of spray and plant growth regulators significantly reduced the number of days taken to first female flower (35.87) with the treatment combination of t_3p_4 (Spray at 2 and 4 leaf stage + Ethrel @ 150 ppm).

The application of ethrel significantly reduced the number of days to appearance of first female flower. It might be due to the fact that ethrel increased starch and carbohydrate which ultimately resulted into the appearance of first female flowers. The results obtained are in agreement with Chaurasiya *et al.* (2016) [4] in muskmelon, Ansari and Chowdhary (2018) [3] in bottle gourd and Kumari *et al.* (2019) [13] in bottle gourd.

Number of days taken from fruit set to edible maturity

The data revealed that effect of time of spray, plant growth regulators and their interaction produced significant effect on the number of days taken from fruit set to edible maturity. 2 and 4 leaf stage (t_3) recorded significantly minimum number of days taken from fruit set to edible maturity (26.18). While, Ethrel @ 150 ppm (p_4) found significantly minimum number of days taken from fruit set to edible maturity (25.91) among the various plant growth regulators. Significantly minimum number of days taken from fruit set to edible maturity (23.85) were recorded with the treatment combination of t_3p_4 (Spray at 2 and 4 leaf stage + Ethrel @ 150 ppm).

The early maturity of fruit might be a result of the application of ethylene. Similar results were also reported by Gedam *et al.* (1998) [6] in bitter gourd, Patil and Bendale (2003) [17] in okra and Sureshkumar *et al.* (2016) [20] in bitter gourd.

Number of male flowers per vine

Various time of spray, plant growth regulators and their interaction produced significant effect on number of male flowers per vine. Minimum number of male flowers per vine (154.34) was recorded at 2 and 4 leaf stage (t_3). In case of the plant growth regulators, minimum number of male flowers per vine (152.71) were observed with Ethrel @ 150 ppm (p_4). The interaction effect of time of spray and plant growth regulators produced minimum number of male flowers per vine (140.20) with the treatment combination of t_3p_4 (Spray at 2 and 4 leaf stage + Ethrel @ 150 ppm).

Suppression of the male flowers by ethrel is due to the reduction in endogenous production of gibberellins during the process of differentiation and alteration on the proportion of gibberellins to the auxins, which gradually induces the suppression of male flower production and induction of more female flowers (Aishwariya *et al.,* 2019) [1] and 2 and 4 leaf stage are critical stage for the change in sex expression. These results are in conformity with the findings of Hill *et al*. (2010) [9] in ridge gourd, Nagamani *et al*. (2015) [15] in bitter gourd, Chourasiya *et al*. (2016) [4] in muskmelon, Mangave *et al*. (2017) [14] in bitter gourd, Ansari and Chowdhary (2018) [3] in bottle gourd and Kadi *et al*. (2018) [11] in cucumber.

Number of female flowers per vine

The data revealed that effect of time of spray, plant growth regulators and their interaction produced significant effect on the number of female flowers per vine. 2 and 4 leaf stage (t_3) recorded significantly maximum number of female flowers per vine (26.19). In case of the plant growth regulators, application of Ethrel @ 150 ppm (p_4) found maximum number of female flowers per vine (25.73). Maximum number of female flowers per vine (29.13) were recorded with the treatment combination of t_3p_4 (Spray at 2 and 4 leaf stage + Ethrel @ 150 ppm).

This might be due to the sexual differentiation is controlled by endogenous levels of auxins, which developed flowering primordia and during flowering act as anti-gibberellin substance. This anti-gibberellin effect might have suppressed the staminate flowers and promoted more number of pistillate flowers (Sulochanamma, 2001) [19]. These results are in conformity with the findings of Ghani *et al.* (2013) [7] in bitter gourd. Exogenous application of plant growth regulators can alter the sex ratio and sequence, if applied at the 2 and 4 leaf stage, which is the critical stage at which the suppression or promotion of either sex is possible (Hossain *et al*., 2006) [10].

Table 2: Effect of time of spray, plant growth regulators and their interaction on various flowering parameters of muskmelon (*Cucumis melo* L.)

Plant growth regulators (p)	Number of days taken to first male flower				Number of days taken to first female flower				Number of days from fruit set to edible maturity			
	Time of spray (t)											
	t_1	t_2	t_3	Mean	t_1	t_2	t_3	Mean	t_1	t_2	t_3	Mean
p_1 (NAA @ 100 ppm)	33.86	38.53	34.60	35.67	42.13	42.73	41.67	42.18	29.53	29.07	28.27	28.96
p_2 (NAA @ 150 ppm)	34.80	39.53	35.07	36.47	41.13	41.80	36.93	39.96	27.07	27.47	27.87	27.47
p_3 (Ethrel @ 100 ppm)	35.80	35.75	35.87	35.80	41.07	41.20	35.93	39.40	26.67	27.40	24.00	26.02
p_4 (Ethrel @ 150 ppm)	37.73	35.80	35.80	36.44	40.00	40.93	35.87	38.93	26.60	27.27	23.85	25.91
p_5 (GA_3 @ 10 ppm)	35.20	34.40	33.87	34.49	41.40	42.00	37.00	40.13	28.67	27.33	25.00	27.00
p_6 (GA_3 @ 20 ppm)	34.27	34.67	32.80	33.91	42.93	44.13	45.33	44.13	26.80	27.40	28.07	27.42
Mean	35.28	36.44	34.67		41.44	42.13	38.79		27.56	27.66	26.18	
	t	p	t × p		t	p	t × p		t	p	t × p	
S. Em. ±	0.42	0.59	1.02		0.43	0.62	1.07		0.33	0.46	0.80	
C. D. (5%)	1.20	1.70	2.94		1.25	1.77	3.06		0.93	1.32	2.29	
C. V. %	5.00				4.52				5.10			

Note: t_1: 2 leaf stage, t_2: 4 leaf stage, t_3: 2 and 4 leaf stage

Table 3: Effect of time of spray, plant growth regulators and their interaction on various flowering parameters of muskmelon (*Cucumis melo* L.)

Plant growth regulators (p)	Number of male flowers per vine				Number of female flowers per vine				Sex ratio (Male: female)			
	Time of spray (t)											
	t_1	t_2	t_3	Mean	t_1	t_2	t_3	Mean	t_1	t_2	t_3	Mean
p_1 (NAA @ 100 ppm)	163.27	166.93	150.80	160.33	22.60	22.07	25.13	23.27	7.23	7.57	6.02	6.94
p_2 (NAA @ 150 ppm)	161.80	164.80	146.93	157.84	23.60	23.13	27.20	24.64	6.88	7.14	5.41	6.48
p_3 (Ethrel @ 100 ppm)	157.40	163.13	144.87	155.13	24.00	23.67	27.80	25.16	6.60	6.89	5.24	6.24
p_4 (Ethrel @ 150 ppm)	157.20	160.73	140.20	152.71	24.27	23.80	29.13	25.73	6.49	6.82	4.82	6.04
p_5 (GA_3 @ 10 ppm)	156.27	159.00	170.87	162.04	23.53	22.53	26.87	24.31	6.64	7.08	6.36	6.69
p_6 (GA_3 @ 20 ppm)	166.53	164.67	172.40	167.87	20.20	22.47	21.00	21.22	8.26	7.36	8.21	7.94
Mean	160.41	163.21	154.34		23.03	22.94	26.19		7.02	7.14	6.01	
	t	p	t × p		t	p	t × p		t	p	t × p	
S. Em. ±	2.25	3.19	5.52		0.34	0.48	0.84		0.14	0.19	0.34	
C. D. (5%)	6.47	9.16	15.86		0.98	1.39	2.41		0.39	0.56	0.96	
C. V. %	6.00				6.05				8.65			

Note: t_1: 2 leaf stage, t_2: 4 leaf stage, t_3: 2 and 4 leaf stage

Sex ratio

Various time of spray, plant growth regulators and their interaction produced significant effect on sex ratio. Significantly lowest sex ratio (Male: female) (6.01) was found at 2 and 4 leaf stage (t_3). In case of the plant growth regulators, lower sex ratio (Male: female) (6.04) was noticed with the application of Ethrel @ 150 ppm (p_4). The interaction effect of time of spray and plant growth regulators found minimum sex ratio (Male: female) (4.82) with the treatment combination of t_3p_4 (Spray at 2 and 4 leaf stage + Ethrel @ 150 ppm).

The exogenous application of ethrel might have altered the sex ratio and sequence of flowering in cucurbits by increasing the female flower production and suppressing the male flower production. This might be due to the retardation of starch digestion, transpiration and respiration in plant tissues after ethrel treatment (Aishwariya *et al*., 2019) [1]. These results are in conformity with the findings of Chourasiya *et al*. (2016) in muskmelon, Shafeek *et al*. (2016) [18] in summer squash and Kadi *et al*. (2018) [11] in cucumber. The sex differentiation within the plant takes place at early stage of growth *i.e.,* at 2 and 4 leaf stages and plant growth regulators applied at this particular stage were found to be effective in alteration of the sex. Moreover, at this particular stage the floral primordia either male or female can be chemically suppressed or enhanced by foliar feeding of growth hormones. These findings are in close conformity with Choudhary and Phaldak (2002) [5] in cucumber.

Conclusions

On the basis of results obtained from the present investigation, it can be concluded that the application of Ethrel @ 150 ppm at 2 and 4 leaf stage is the best in terms of growth and flowering parameters in muskmelon.

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